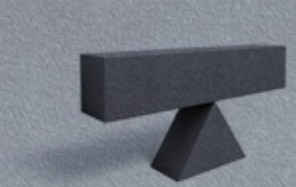
Broad Customer Base

Widest Range of Technologies

Growth Platform

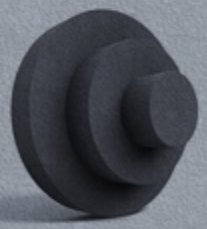


KELLER

Application of Micropiles for Uplift Control and Foundation of Large Access Ramps of an Underwater Road Tunnel in Gdańsk

MSc. Civ. Eng. Oskar Mitrosz

Keller Polska Sp. z o.o.



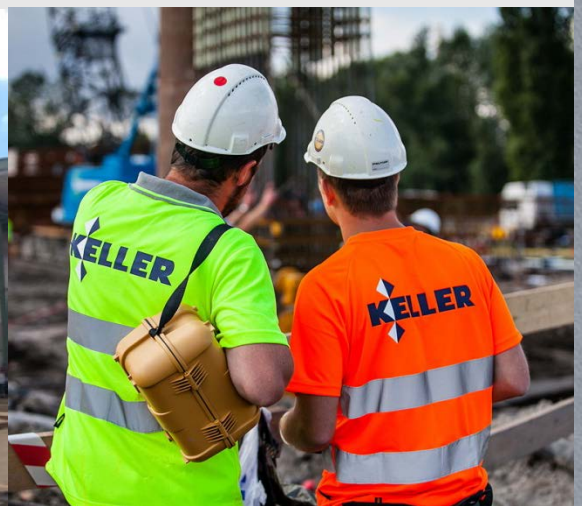
Local Focus

Deep Experience

Global Scale

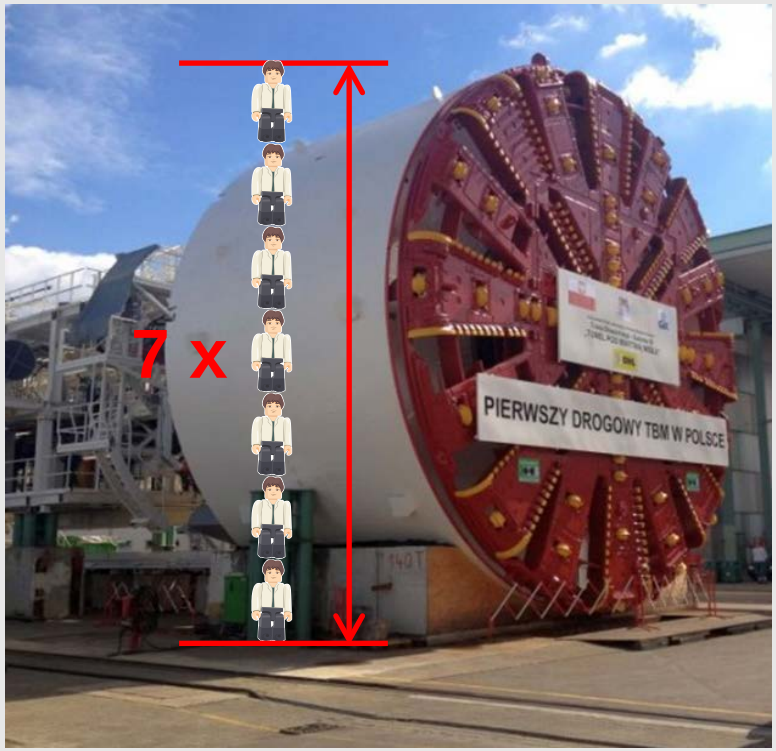
Scope of presentation

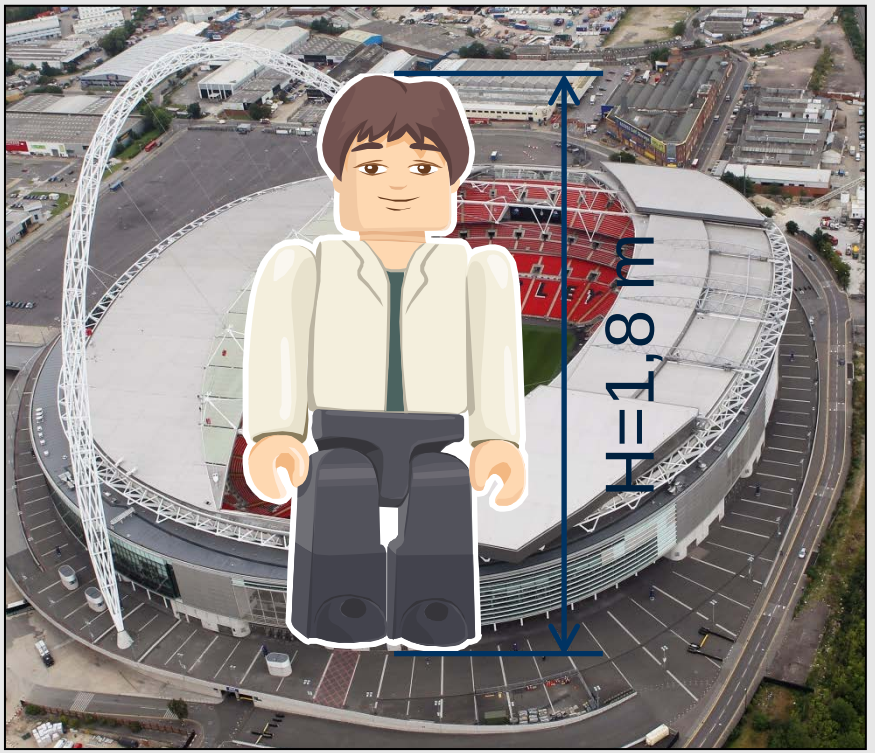
- General Project overview
- Geotechnical conditions
- „WET” vs. „DRY” excavation pit protection
- Design aspects of anchoring systems
- Quality control and monitoring
- Conclusions



General Project overview - Gdańsk (North Poland)

General Project overview - main information

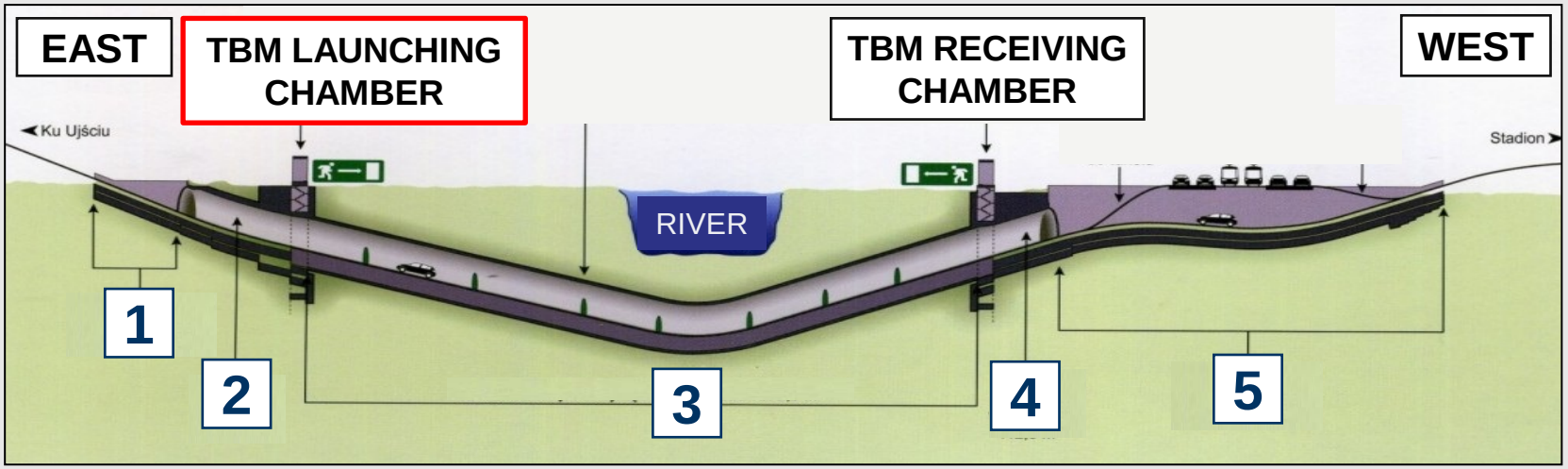




- First Road Tunnel ever done by TBM in Poland
- Polish record TBM shield Ø 12,6 m (2 tubes)
- Total volume of exctracted spoil (~1,0 mln m³) big enough to fill up the Wembley Stadium full
- Over 3,300 micropiles installed (ca. 38.5 km)

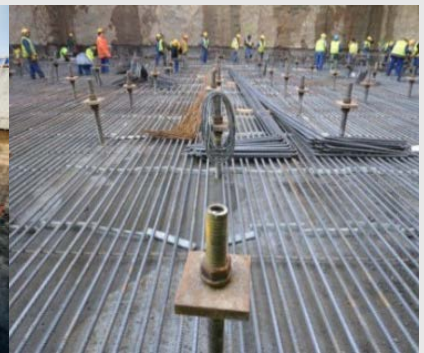
General Project overview - Gdańsk (North Poland)

General Project overview - longitudinal cross section

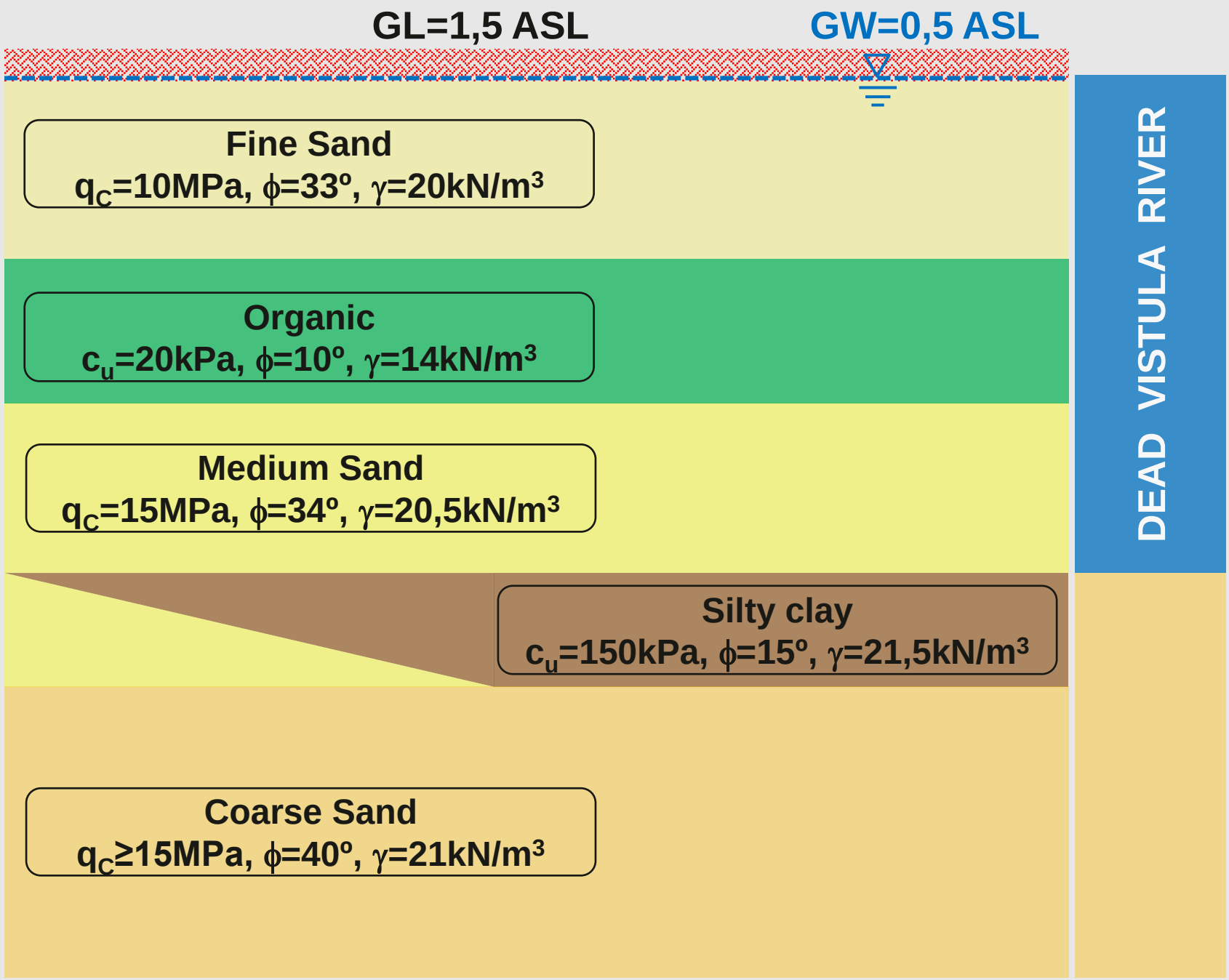


No.	Section	Length, [m]	Max. excav. depth, [m]
1.	U section in open pit	147.5	8.5
2.	Tunnel in open pit (eastern bank)	192.5	20.5
3.	TBM section (2 x ø12.56 m)	1 072.5	--
4.	Tunnel in open pit (western bank)	112.5	22.0
5.	Tunnel in open pit and roundabout	630.0	13.2

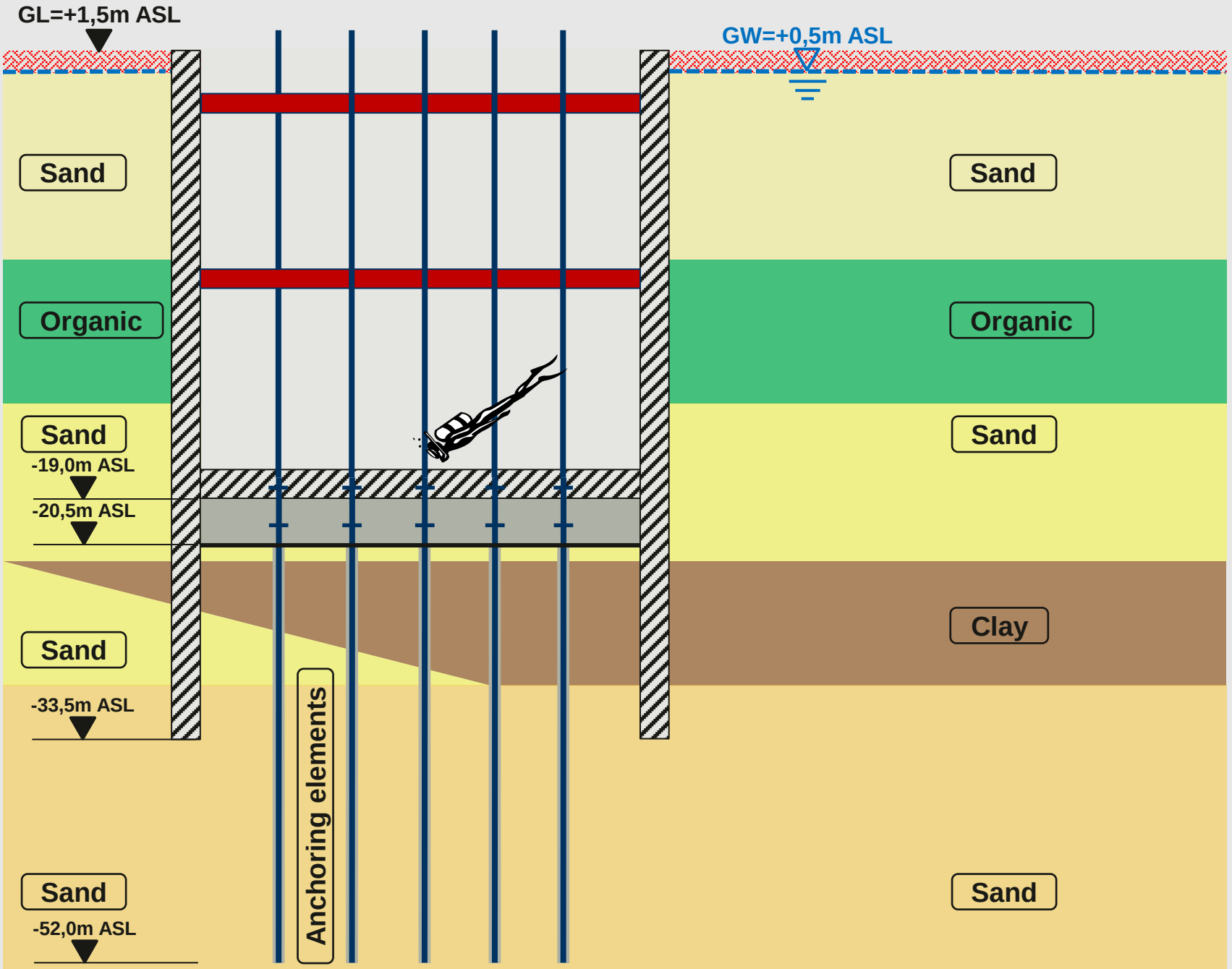


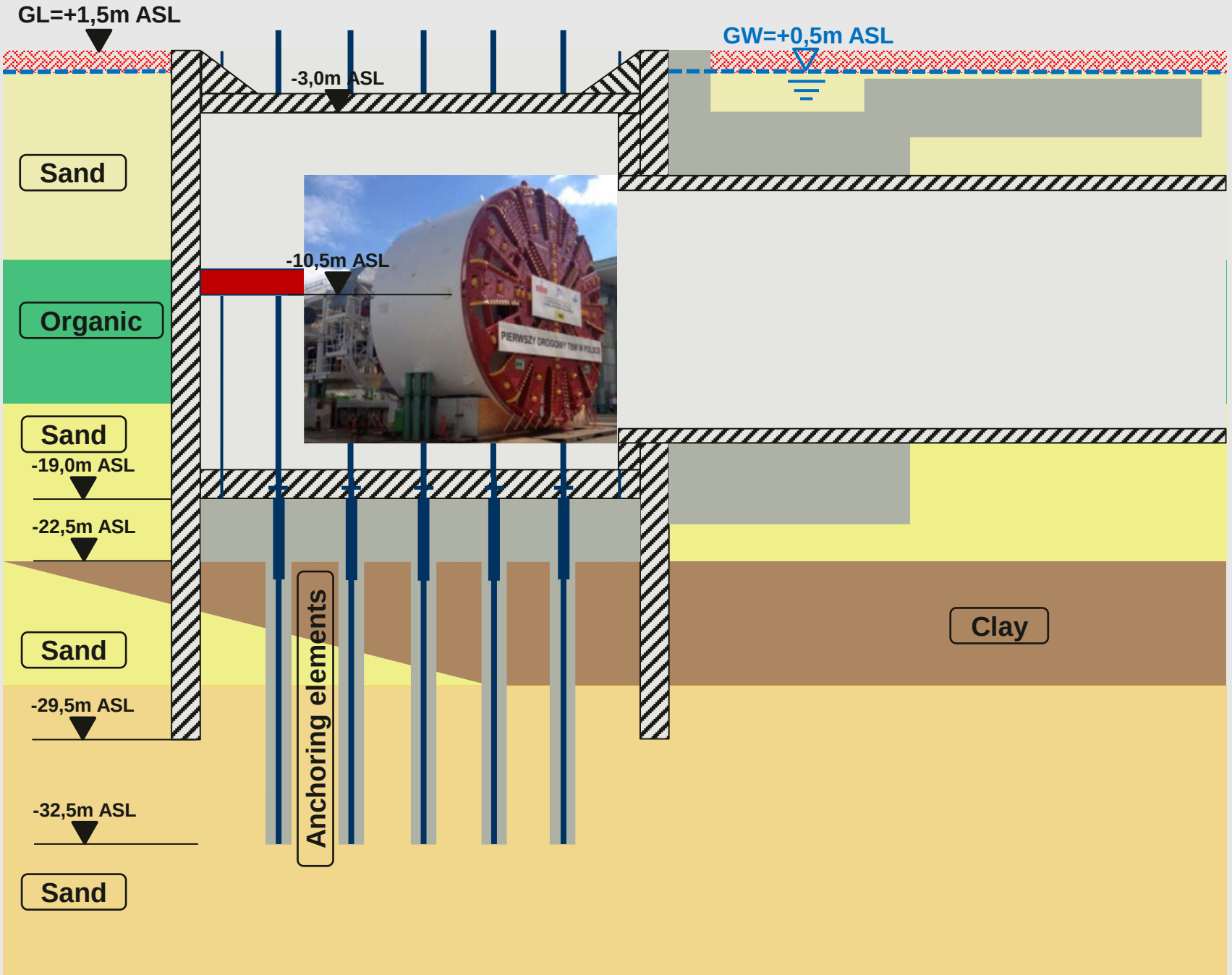
Geotechnical conditions – TBM launching chamber



Construction phases – Primary solution („WET”)



Construction phases – Adopted solution („DRY”)



Construction phases – Adopted solution („DRY”)

Construction phases – Adopted solution („DRY”)

Design aspects of anchoring systems

1. Structural capacity of an anchoring element

- DYWI-Drill hollow bar T76 (steel class 28 Mn 6)
- Steel deduction due to corrosion (3.25 mm / 100 years)
  - A_{nom} = 24.68 cm^2 A_{corr} = 17.57 cm^2

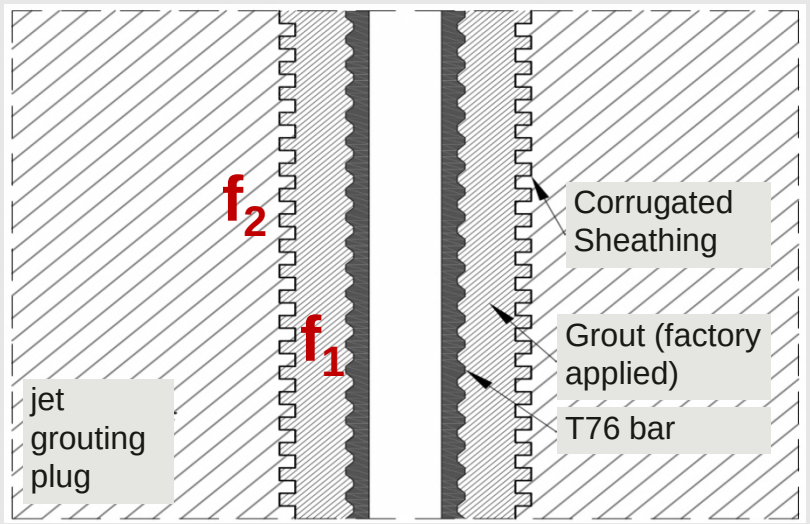
- Allowable tensile capacity
  - $P_{allow} = f_{yd} \cdot A_{nom}$ = **968 kN** (temporary stages) **> R_{max} = 791 kN**
  - $P_{allow} = f_{yd} \cdot A_{corr}$ = **689 kN** (permanent stage) **> R_{max} = 589 kN**

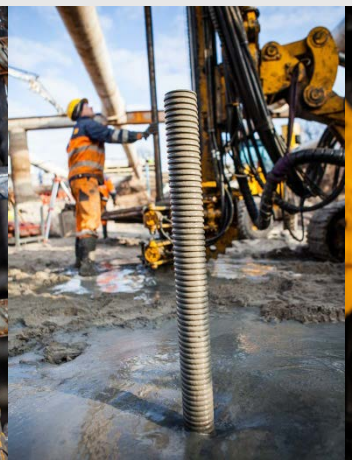
Design aspects of anchoring systems

2. Bond capacity

- Ultimate bond stress tested on trial elements on site
  - f_1 = 1.05 MPa f_2 = 0.63 Mpa
- Length and circumference of hallow bar / encapsulated part
  - L_{pile} = 10.0 m C_{pile} = 0.239 m
  - L_{encap} = 3.5 m C_{encap} = 0.503 m
- Allowable pull-out capacity
  - $P_{allow} = f_1 \cdot C_{pile} \cdot L_{pile}$ = **2509 kN**
  - $P_{allow} = f_2 \cdot C_{encap} \cdot L_{encap}$ = **1109 kN**

> R_{max} = 791 kN



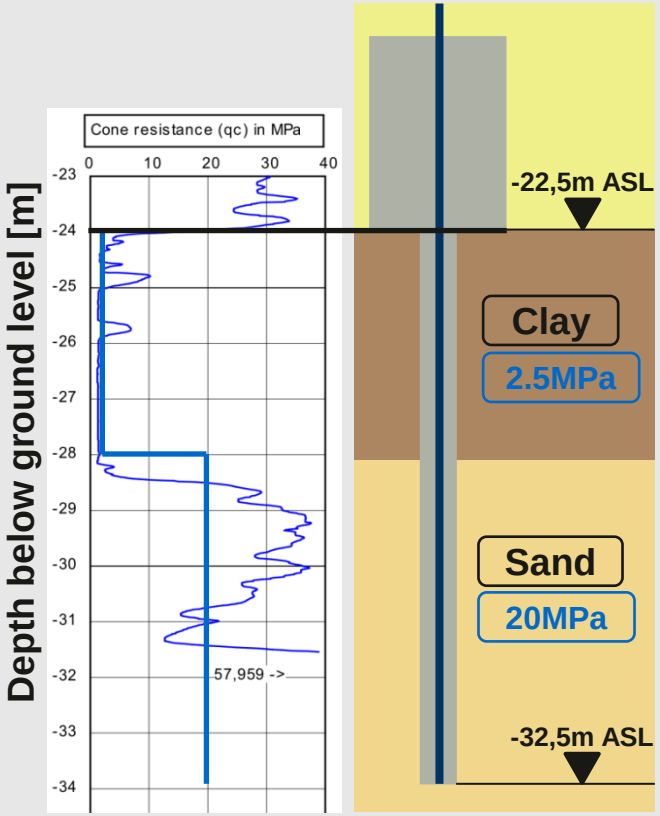


Design aspects of anchoring systems

3. External capacity of an anchoring element (jet grouting column)

- Ultimate bearing capacity
  - $R_{sk} = \Sigma(q_{ci}/k_{si} \cdot t_i) \cdot \pi D$
  - $R_{sk} = (2.5/40 \cdot 4 + 20/150 \cdot 6) \cdot \pi 1.0 = 3297$ kN
- Allowable bearing capacity
  - $P_{allow} = 3{,}297/2.0 =$ **1640 kN**

$> R_{max} =$ 791 kN



4. Bearing plate capacity

- Allowable loading (max. contact pressure)
  - $P_{allow} = f_{cd} \cdot A_{sp,eff} = 20000 \cdot 0.058 =$ **1160 kN**

$> R_{max} =$ 791 kN

- Allowable loading (punching)
  - $P_{allow} = f_{ctd} \cdot C_m \cdot h = 1330 \cdot 2.2 \cdot 0.4 =$ **1170 kN**

$> R_{max} =$ 791 kN

Design aspects of anchoring systems

5. Global stability against uplift (UPL)

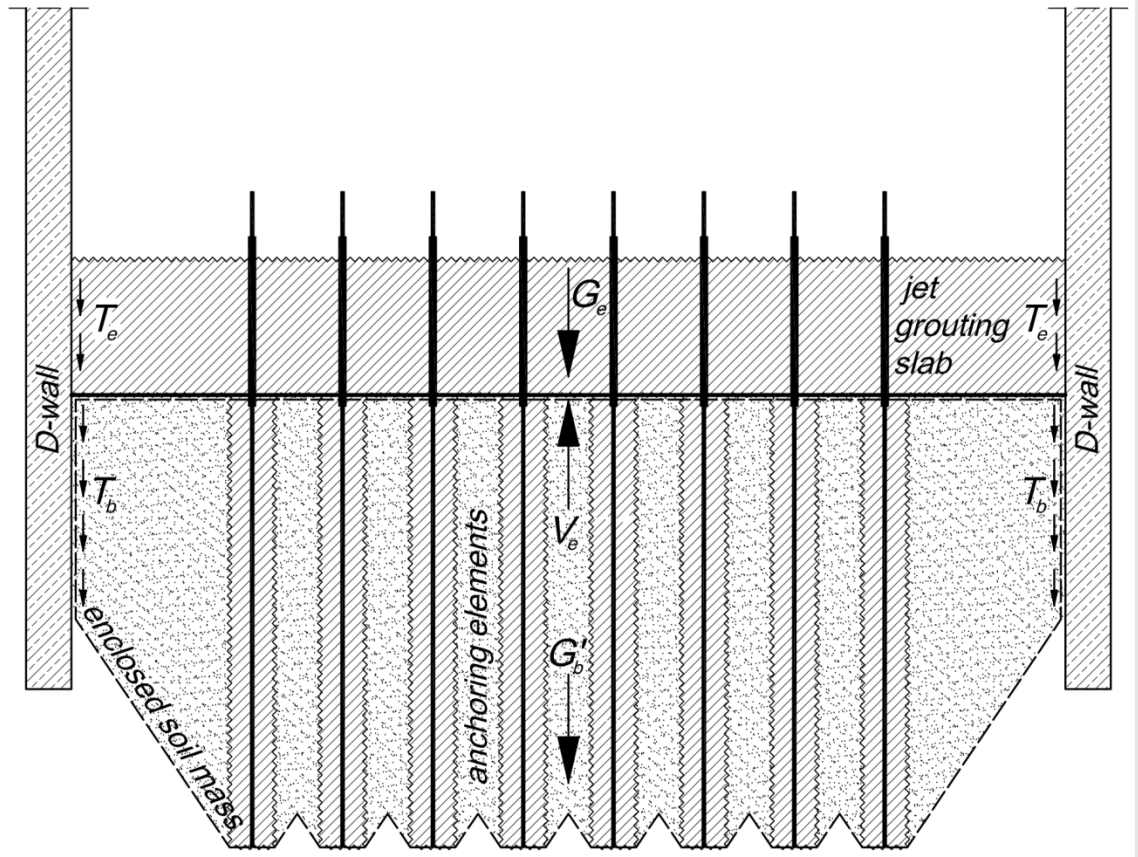
- Temporary stage 1a (decisive)
  - $V_e \cdot \gamma_{dst} \leq (G_e + 2T_e + G'_b + 2T_b) \cdot \gamma_{stb}$

where:

V_e – uplift forces (destabilising actions)

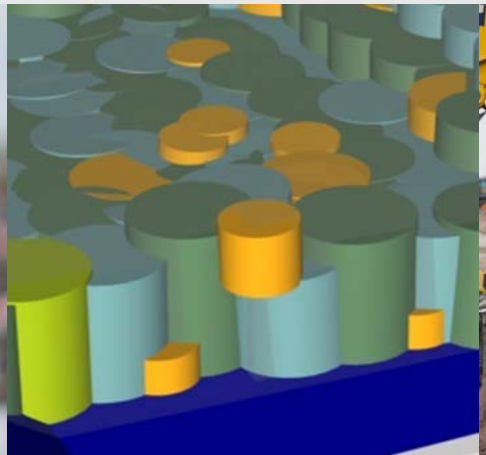
G_e, G'_b, T_e, T_b – dead weights and friction forces (stabilising actions)

$\gamma_{dst/stb}$ – partial safety factors (acc. to EC7 γ_{dst}=1.0, γ_{stb}=0.9)



Quality control and monitoring

- QC prior to production on site:
  - Trial jet grouted columns (diameter)
  - Tests of strength and permeability (samples)
  - Pull-out tests of anchoring elements (hollow bars)
- QC while production on site:
  - Positioning control system utilising local GPS
  - Inclinometer measurements of every jet grouting column
  - Automatic printouts
  - Constant verification (3D visualizations)
  - Lab tests of used materials (cement grout, steel)
- Monitoring:
  - Precise geodesic monitoring of jet grouting plug
  - Measurements of GW (in / out of excavation)



Conclusions

- Main challenges:
  - High GW levels
  - Poor ground conditions
  - Very deep excavations
  - Extreme drilling depths
  - Decoupling hollow bars
  - Complex geotechnical solutions demanding 7 technologies
- Benefits of „DRY” method:
  - Safe
  - Cost effective
  - Time efficient

Are there any limits for geotechnique?

Thank You…